

APPLICATION
FOR
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**TITLE: SUBMERSIBLE PUMP DEPLOYMENT AND
RETRIEVAL SYSTEM**

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SUBMERSIBLE PUMP DEPLOYMENT AND RETRIEVAL SYSTEM

Cross-reference to related applications

[0001] This application claims the benefit, pursuant to 35 U.S.C. §119(e), of U.S. Provisional Application No. 60/458,860, entitled, "Submersible Pump Deployment and Retrieval System," filed on March 28, 2003. That application is incorporated by reference in its entirety.

Background Art

[0002] The invention of the electrically actuated submersible pumps by Armais Arutunoff in 1933 started an era where electrical power replaced mechanical force as the method used to transmit the necessary power to downhole pumps for the extraction of various materials. Since the Arutunoff invention, methods have been improved to take advantage of the unique characteristics of the pump and power source. The most significant improvement was the dramatic reduction in the mass and size of the elements used to transmit the power and to react the resulting forces. For example, steel rods were replaced with much lighter electrical cable and heavy production tubing once required to react mechanical actuation was replaced with much lighter production tubing.

[0003] The successful installation of an electrical submersible pump in a well usually requires that several steps and functions take place. The first step is the suspension of the mass of the production string either from the wellhead or the casing. As that term is typically used, the production string includes everything inside the casing below the wellhead, and typically includes the production tubing, the fluid inside the production tubing and the electrical cable. Secondly, there must be proper conveyance of the pumped fluid from the pump to the surface, typically through a closed tube. Finally, electrical power must be conveyed from the surface to the pump. For example, modern electrical submersible pumps are installed in drilled wells that may have been cased with steel pipe,

and have installed inside the casing production tubing that consists of 30 foot sections of 2 inch production tubing that are screwed together to form a continuous pipe. Attached to the production tubing is a multi-conductor electrical cable used to provide power to the pump. The electrical cable is typically banded to the production tubing every 10 feet, and is installed outside the production tubing. Two of the required functions are accomplished by the production tubing, namely suspension of the mass and conveyance of the pumped fluid. The third function, conveyance of electrical power, is accomplished by the electrical cable banded to the production tubing.

[0004] Numerous attempts have been made to improve conventional practice by combining two or three of these functions into a single structure that can be spooled on a reel and deployed continuously into the well. Lighter (hence cheaper) structures can be obtained by this combination, and easier installation is the result of a continuous structure that can be conveniently transported and deployed into the well from a reel. Another significant advantage is the ability to quickly and easily remove the pump for maintenance. As early as 1968, U.S. Patent No. 3,411,454 proposed a flexible cable that consisted of strong steel fibers interwoven with electrical conductors to form a cable that provides electrical power and load suspension. An additional structure, a liner, was used to convey fluids from the pump to the surface. Because the pump was located inside the liner, the pump could be installed and replaced without removing the liner, thus providing most of the advantages of combination.

[0005] Variations of this theme, commonly referred to as cable suspended pumping systems or CSPS, were pursued for the next 20 years. One problem with such systems is the tendency of the electrical cable and the mechanical cable to be incompatible under mechanical load. One solution to this problem was suggested in U.S. Patent No. 4,681,169, which separated the mechanical cable from the electrical cable and loosely attached the cables. This type of system allowed load to be transferred from the electrical cable to the steel cable, but did not tightly tie the two together. However, this approach did not address the conveyance of fluids from the pump to the surface. With the introduction of coiled production tubing, the load suspension element was changed from

wire rope to coiled production tubing, and many variations of combinations of coiled production tubing and electrical cable were patented.

[0006] One example of a cable suspended pumping system is illustrated in U.S. Publication No. 20020108757. The method is intended to solve the issues of incompatibility between the power conduit, suspension cable, and the coiled production tubing by providing a means for the cables to lengthen different amounts when loaded. In this example, the power conduit, suspension cable, and the coiled production tubing are combined at the surface using removable clamps as the pump is lowered into the well. The clamps are spaced relatively far apart to allow the three elements to expand or contract between the clamps without damage.

[0007] U.S. Patent No. 5,906,242 issued to Bruewer illustrates another typical system, wherein the coiled or jointed tubing bears the weight of the pump and the electrical cable. The coiled or jointed tubing is filled with a fluid having sufficient density to float the particular electrical cable being used. Both the coiled or jointed tubing and flexible steel cable combined with electrical cable accomplished the suspension and electrical power conveyance, but required that an additional function, namely fluid conveyance to the surface, be accomplished by another structure. This would typically be accomplished by a liner or the well casing.

[0008] An alternative approach is expressed in U.S. Patent No. 3,411,454, which proposed a flexible cable that consisted of strong steel fibers interwoven with electrical conductors to form a cable that provides electrical power and load suspension. However, high axial loads on the cable may cause cable failures.

[0009] What is still needed, therefore, is a system for suspending a submersible pump in a well wherein a single component accomplishes both the power conveyance and the load suspension.

Summary of Invention

- [0010] In one aspect, the present invention relates to a system for pumping fluids out of a well. The system comprises a power conduit operatively connected to a submersible pump.
- [0011] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

Brief Description of Drawings

- [0012] Figure 1 is a schematic side view of an installed submersible pump in accordance with one embodiment of the invention.
- [0013] Figure 2 is a schematic side section view of an adaptor with an inflatable packer in accordance with one embodiment of the present invention.
- [0014] Figure 3 is a side section view of an installed submersible pump in accordance with one embodiment of the invention.
- [0015] Figure 4 is a side section view of an installed submersible pump in accordance with one embodiment of the invention.
- [0016] Figure 5 is a side section view of an installed submersible pump in accordance with one embodiment of the invention.
- [0017] Figure 6 is a flowchart of a method in accordance with one embodiment of the invention.

Detailed Description

- [0018] In one or more embodiments, the present invention relates to suspending a submersible pump in a well by using a power conduit that also provides the suspension of the pump. More specifically, the power conduit has a substantially neutral buoyancy when submersed in the well fluid. The buoyancy reduces the mechanical loading of the power conduit that is attributed to the weight of the power conduit.

[0019] Figure 1 illustrates a system in accordance with one embodiment of the present invention. In Figure 1, a liner 5 is installed inside of a well casing 7. A backflow preventer is located proximal to the distal end (*i.e.*, the end closest to the well bottom) of the liner 5. In one embodiment, the backflow preventer comprises a check valve 8. In a typical embodiment, the liner 5 is then filled with a fluid 4. The fluid 4 may be provided from the well or pumped into the well from an outside source. Typically, the fluid 4 is water based. The check valve 8 is adapted such that the fluid 4 is allowed to flow through the check valve 8 from below, but fluid is prevented from flowing from above. This function allows the liner 5 to stay filled with the fluid 4. While the backflow preventer is shown as a check valve 8, one of ordinary skill in the art will appreciate that other mechanisms could provide a similar function without departing from the scope of the present invention. Other backflow preventer options could include valves operated by electrical power conveyed through the power conduit. The backflow preventer could also be integrated into the submersible pump such that flow is only allowed to flow in one direction. In some instances, if the formation has a high enough pressure, a sufficient column of fluid can be supported without a backflow preventer.

[0020] After the liner 5 is sufficiently filled with the fluid 4, a submersible pump 1 is lowered into the well and supported by a power conduit 2. The power conduit 2 and the fluid 4 have similar densities. Whether the liner 5 is “sufficiently filled” is determined by the strength of the power conduit 2 and the ability to support the free hanging weight of the power conduit 2 and the submersible pump 1. The portion of the power conduit 2 that is submerged in the fluid 4 is supported by the buoyancy of the power conduit 2. This reduces the loading on the power conduit 2 caused by the weight of the power conduit 2.

[0021] In the pictured embodiment, a packer 3 is located above the submersible pump 1. The power conduit 2 passes through a feedthrough 11 and is connected to the submersible pump 1. In other embodiments, the packer 3 may be disposed below the submersible pump 1, which would allow the power conduit 2 to be directly connected to the submersible pump 1. After reaching the appropriate location in the well, the packer 3 is activated to seal between the liner 5 and the submersible pump 1. Once the packer 3 is activated, the weight of the submersible pump 1 may be fully supported by the packer 3.

[0022] After being fully installed, the submersible pump 1 may be turned on from the surface by power conveyed through the power conduit 2. Typically, power is supplied by hydraulic pressure or electricity. The submersible pump 1 may accordingly be operated by hydraulic pressure or electricity conveyed through the power conduit 2. When the submersible pump 1 is operating, fluid 4 flows from perforations 10 into the well casing. Then, the fluid 4 flows through the check valve 8 into the liner 5. The fluid 4 is taken into the pump inlet 9, through the submersible pump 1, and out into the liner 5 after exiting through the pump outlet 6. Fluid 4 flows from that point up towards the surface. The fluid flow is indicated in Figure 1 by arrows.

[0023] Submersible pumps wear out over time depending on the particular submersible pump and the conditions in the well. The well ceases to produce once the submersible pump fails. After a submersible pump failure, the submersible pump is brought to the surface and replaced. Typically, retrieval of the submersible pump is accomplished using the system that was used for deploying of the submersible pump. Replacing the submersible pump requires releasing the sealing device so that the submersible pump can be pulled to the surface by the power conduit.

[0024] Figure 2 illustrates a release mechanism in accordance with one embodiment of the present invention. One suitable release mechanism known in the art is an inflatable packer 203. The inflatable packer 203 is activated by differential pressure experienced in the well. In this example, the inflatable packer 203 is installed above the submersible pump, not shown. The power conduit 2 passes through a feedthrough 11 to connect to the submersible pump. In order to release this particular inflatable packer 203, there is a packer release mechanism 201, which deflates the inflatable packer 203 when tension is applied by the power conduit 2. There are many sealing device options with various release mechanisms that may be suitable for the present invention. For example, an inflatable packer may have a small orifice that leaks pressure gradually. When the submersible pump deactivates, the small orifice deflates the inflatable packer by equalizing the pressure above and below the inflatable packer. One of ordinary skill in the art will appreciate that the sealing device and release mechanism may vary without departing from the scope of the invention.

[0025] Turning to Figure 3, another embodiment of the present invention is shown. In this embodiment, a packer 301 is shown installed directly into the well casing 7. The packer 301 has a profile on top that enables a shoe 302 to seal using a shoe seal 303. The packer 301 may be installed using any means known in the art, such as a wire line. A shoe 302 can then be run into the well and seal against the packer 301 using the shoe seal 303. Typically, the shoe 302 would be run into the well using wire line that is attached to the shoe 302 by the wire line connection groove 304. A check valve 8 is installed inside of the shoe 302 to maintain fluid in the casing above the packer 301. After the above items have been installed, fluid 4 would fill the casing as discussed with respect to Figure 1.

[0026] Continuing with Figure 3, a submersible pump 1 is run into the well while attached to the power conduit 2, which has a density substantially equal to the fluid 4. The submersible pump 1 includes a pump seal 306, which seals against the shoe 302. The weight of the submersible pump 1 would then be supported by the shoe 302 and the packer 301. Once the submersible pump 1 seals against the shoe 302, the submersible pump 1 can be powered by power conveyed through the power conduit 2. At that point, the submersible pump 1 would pump fluid 4 from below the packer 301 to the surface. The fluid 4 would be conveyed to the surface through the casing 7.

[0027] As discussed with respect to Figures 1 and 2, the submersible pump 1 will eventually require replacement. In the embodiment illustrated in Figure 3, the packer 301, check valve 8, and the shoe 302 may be permanently installed into the well. When the submersible pump 1 is turned off, the submersible pump 1 may be pulled to the surface by the power conduit 2. In this configuration, a release valve 305 is included above the submersible pump 1. The release valve 305 would relieve the pressure difference above and below the submersible pump 1 allowing the power conduit 2 to retrieve the submersible pump 1 with minimal force. The release valve 305 may operate by tension in the power conduit 2, a small orifice that relieves pressure when the submersible pump 1 is turned off, or any other means known in the art. One of ordinary skill in the art will appreciate that other devices could be used to aid the release of the submersible pump without departing from the scope of the invention. If no release

mechanism is used, then the power conduit 2 would provide the force required to overcome the pressure differential that exists above and below the pump. A release mechanism would reduce this force requirement.

[0028] Figure 4 illustrates another embodiment in accordance with the present invention. A liner 5 is shown in the well. A seating nipple 402 is disposed on the end of the liner 5. A shoe 302 is installed inside the liner 5 and includes a seal 401 that is adapted to seal against the seating nipple 402. A check valve 8 is installed inside of the shoe 302. After installation of these components, a submersible pump would be installed as discussed with the previous embodiments. Fluid would be conveyed to the surface through the liner 5. One of ordinary skill in the art will appreciate that the liner could be any other tubing, such as jointed pipe or coiled tubing, without departing from the scope of the present invention.

[0029] Turning to Figure 5, a pumping system in accordance with an embodiment of the present invention is shown. The embodiment shown in Figure 5 is similar to that of Figure 4. The submersible pump is a hydraulically driven submersible pump 502. Pressure is conveyed through the power conduit to power the hydraulically driven submersible pump 502. In this embodiment, the power conduit comprises twin floating hydraulic tubing 501. The twin floating hydraulic tubing 501 would have a density substantially equal to the fluid 4.

[0030] Several methods are available to create power conduit that has substantially neutral buoyancy. The term "neutral buoyancy," when applied to the power conduit, refers to the power conduit having a density near the density of the fluid in the well. When the power conduit has neutral buoyancy, the power conduit does not experience increased loading from the weight of the power conduit. The weight of the power conduit is fully supported in that case. If the power conduit is too buoyant, it may be unable to lower the submersible pump into the well because the power conduit will float and lift the submersible pump. Excess buoyancy will also create tension in the power conduit. Whether the power conduit is "too buoyant" will depend on the weight of the submersible pump and the tensile strength of the power conduit. Alternatively, if the

power conduit has less than neutral buoyancy, the tension in the cable will increase with length. The negative buoyancy that can be allowed will vary based on the weight of the submersible pump and the tensile strength of the power conduit.

[0031] In some embodiments of the present invention which employ electrical submersible pumps, the power conduit is constructed of at least two types of materials. For example, in one embodiment, a power conduit comprises an electrical conductor, which conveys electricity to the pump, and an insulating material. In an alternative embodiment, multiple power conduits are combined by extruding a sleeve over the power conduits to form a single structure. The conducting material may be formed of a metal, copper or aluminum, for example. These materials have a density greater than 1.0 g/cc. The insulating material may be formed from a plastic material having a density of less than 1.0 g/cc. By adjusting the relative amounts of these two materials, an overall density of the cable of 1.0 g/cc can be achieved, which is equal to the density of water. The overall density of the cable may be adjusted if the fluid in the well has a different density.

[0032] As an example of a power conduit design in accordance with an embodiment of the invention, a number 10 copper conductor with a diameter of 0.102 inches is used. The area of the conductor is 0.00817 square inches. The density of the copper conductor is 8.93 g/cc. If a low density polyethylene, or polypropylene insulator is used, the specific gravity of the sleeve will be about 0.90 g/cc. If copper conductor is round, and the inside diameter of the insulating layer is the outside diameter of the copper, then neutral buoyancy can be obtained by adjusting the outside diameter to achieve an average specific gravity of 1.00. The equation for the cable to have a specific gravity of 1.00 is: Area of the conductor X specific gravity of the conductor equals Area of the insulator X specific gravity of the insulator. Assuming copper and polyethelene, and a number 10 conductor, solving for the outside diameter of the insulator gives an outside diameter of about 0.34 inches. To power some submersible pumps, three of these cables would be twisted together. The combination of the three cables results in a diameter of about 0.75 inches.

[0033] In some applications, a diameter of 0.75 inches may be too large. To decrease the diameter of the power conduit, a lower density material can be created by using lower density polyethylene, foaming polyethylene, or by filling the polyethylene with a low density filler such as glass microballons, or low molecular weight filler material such as polywax 500 available from Baker-Hughes Petrolite division. At great depths, the glass microballons may be preferred due to the tendency of foamed materials to collapse under extreme pressures.

[0034] In addition to the filler, a strength member such as a polyamide (Kevlar) rope may be added to reduce density and add strength. Another method to reduce the bulk of the neutral density cable is to use aluminum conductors in place of copper. This will reduce the weight of the conductors for the same current carrying capabilities, further reducing the bulk of the low density component of the cable. Aluminum does have the disadvantage of being reactive in some environments, so care must be taken to protect the conductors, especially in areas where well fluids may enter. Examples of methods to protect an aluminum conductor include coatings or jackets made of non-reactive materials.

[0035] The buoyancy of the power conduit may be adjusted by the attachment of weights and floats at various locations along the length of the power conduit. This additional adjustment allows the power conduit to be adapted to a particular well fluid after the power conduit has been manufactured. In some cases, the well fluid may be water with dissolved salt such that the overall density of the well fluid is 1.1 g/cc. This well fluid would cause a power conduit having an average density of 1.0 g/cc to have positive buoyancy. The power conduit could be weighted at locations along the length so that the average density is 1.1 g/cc to match the well fluid. In a scenario where the power conduit is denser than the well fluid, floats could be attached at locations along the length to make the power conduit more buoyant.

[0036] The various materials of the power conduit can be utilized in varying ratios to suit particular applications. The required electrical power, liner or casing size, fluids in the well, depth, and required strength each factor into the design of the power conduit. One

of ordinary skill in the art will appreciate that the selected materials, ratios of the materials, and overall size of the cable may vary without departing from the scope of the invention.

[0037] In Figure 6, a method in accordance with an embodiment of the invention is shown. In step 610, a check valve, or other backflow preventer, is installed in the distal end of a liner. In other embodiments, the check valve may be installed at another location in the liner that is below the intended location for the submersible pump. Additionally, the check valve may be installed in a casing in the well. In step 620, the liner is filled with a fluid. If the check valve is installed in the casing, the casing would be filled with fluid. Typically, the fluid would comprise water provided from the well or other outside source. In step 630, a submersible pump is deployed using a power conduit having a density similar to the density of the fluid. Then, in step 640, a seal is formed between the inlet and outlet of the submersible pump. In step 650, power is conveyed to the submersible pump through the power conduit.

[0038] While the above discussion was focused on the design to make power conduit for conveying electricity neutrally buoyant, similar principles can be used to design power conduits for conveying hydraulic pressure. To convey hydraulic pressure, the power conduit would typically include a hollow passageway. The hydraulic pressure could be conveyed by a fluid disposed in the hollow passageway. The fluid could be air, oil, or any other suitable fluid. A metal, such as steel, could wrap the power conduit for tensile and pressure capability. The balance and selection of materials for a power conduit to convey hydraulic pressure will vary according to the specific application.

[0039] One factor in the strength requirement of the cable is the weight of the submersible pump when submerged in the well. The weight of the submersible pump will vary according its size and capacity. For example, a submersible pump having a diameter of 2-1/2 inches might weigh 80 pounds when submerged in water. A submersible pump having a diameter of about 4 inches might weigh 160 pounds when submerged in water. One option to reduce the weight of the submersible pump in the well, and the strength requirement of the cable, is to attach buoyant material to the

submersible pump. The 4 inch submersible pump could have enough buoyant material attached so that the weight of the pump decreased to 80 pounds when submerged in the well. Some negative buoyancy is required so that the submersible pump can be lowered into the well. The required negative buoyancy will vary depending on the well geometry and the sealing devices. For example, a shoe typically requires a load to form a seal with the submersible pump.

[0040] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.